"OTHER" QCD TESTS*

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There are two testing grounds for strong-interaction theory (call this QCD) which are not usually included in discussions about either present or future QCD tests: inclusive polarization and exclusive reactions.

Inclusive Polarization

Various hyperons (Λ, $\Sigma^{\pm}$, Ξ^{-}, Ξ^{0}) have been found polarized when produced inclusively in p-p interactions at 28 GeV, 400 GeV, and 2000 GeV (ISR) equivalent proton energy on a hydrogen target.[1] The polarization increases with X_F and with $p_\perp$ (above a $p_\perp$ of 1 GeV/c the polarization appears to have flattened out). At the highest X_F (0.8) and $p_\perp \approx 1$, the polarization of Λs is about 50% at the ISR. At Fermilab, data out to $p_\perp = 2.2$ GeV/c have been published.

The QCD test here is simply that there should not be any polarization. A new Fermilab experiment (T. Devlin et al.) will reach $p_\perp = 4$ GeV/c. The future of this business is not clear. If the polarization at $p_\perp = 4$ is zero, following standard experimental method, the subject will be closed. Some day, of course, the lower $p_\perp$ results should be understood within theory (there, indeed, are some models for it now). On the other hand, higher $p_\perp$ measurements may be needed. This would be most easily accomplished with higher energy experiments, such as with a Tevatron fixed-target experiment, except that one then probes lower X_F. It has already been demonstrated that Λ polarization is smaller at low X_F. One could, however, trace the $p_\perp$ dependence at fixed X_F and ask: Does the effect diminish at high $p_\perp$, as required by QCD?

For colliders, clearly, one should observe some self-analyzing particles and check their polarization.

Exclusive Reactions

There are several types of exclusive tests of QCD which are very different from inclusive tests. Inclusive hard scattering for hadron-hadron machines refers to a region where one quark-quark reaction occurs, and debris from the other spectators is ignored. For wide-angle (or high $p_\perp$) exclusive reactions, one is looking at hard scattering of all the quarks, and the particular case where the debris reforms into specific channels. There are several reasons for doing this: some very large and unanticipated effects have already been seen; the inclusive approximations on the non-contribution of spectators are not there; the QCD calculation is difficult but tractable and the QCD effects in exclusive processes are first order there; qualitatively, one is testing fairly simple ideas--for example, does the hard reaction obliterate the memory of the initial state in the formation of the final state? Clearly, one would like to test QCD in as many different ways as possible, and exclusive reactions provide very different tests than inclusives.

Before discussing possible (and existing) tests, an elemental question must be addressed: can you look at exclusives in a "QCD region"? Exclusive reaction cross sections fall sharply with energy and the highest $p_\perp$ attainable is about 4 GeV/c for 30 GeV/c protons on hydrogen at 90° c.m. Now, there are several pieces of evidence that one can look at exclusives in a hard-scattering region. p-p experiments from 6-12 GeV/c and π-p experiments also at the ZGS both show a developing central region in cross section starting at about 6 GeV/c or $p_\perp = 1.6$ GeV/c, and CIM predicted energy dependence (pp as s^{-10}; πp as s^{-8}) (Fig. 1). A p-p spin-spin experiment also sees that a clear break occurs in the spin-parallel cross section at this $p_\perp$, which is not seen at lower energy and has been shown to be $p_\perp$-dependent and not angle-dependent (Fig. 2). All of this argues that, indeed, exclusive reactions have entered a hard-scattering region at the largest $p_\perp$ for incident beams above 6 GeV/c.

A. Spin-Spin Correlation Tests

It was observed at Argonne[2] that, for p-p elastic scattering, the spin-parallel cross section grows relative to the spin-antiparallel cross section, vs. $p_\perp$, reaching a ratio of 4 at the largest available $p_\perp$ of 2.3.

If one treats the individual quark-quark reactions as independent, this cannot happen.[3] The calculation is a simple one, since one assumes that each spin-up proton has two spin-up quarks and one spin-down, ignores sea contributions which would diminish the effect, and also ignores quark flavors. One finds a maximum ratio of $\sigma_{parallel}/\sigma_{antiparallel} = 2$. Thus, we seem to already have evidence of a collective effect, possibly in contradiction with QCD. A way out is to declare that, despite Figs. 1 and 2, this is not a QCD region.

For the future, the AGS will have polarized protons in 1984 and this effect will be explored out to $p_\perp \approx 4$. If the effect persists, it will be interesting to explore other exclusive spin-effects and compare these with QCD calculations. All this would be done, due to the rapidly vanishing exclusive cross sections, at and below 30 GeV.

B. Flavor-Changing Tests

An experiment has begun at the AGS[4] which measures a large number of two-body exclusive reactions near 90° c.m., for incident momenta 10-18 GeV/c: $\pi^-p \rightarrow p\pi^-$, $p\rho^-$, pA_2^-, $\pi^+\Delta^-$, $K^+\Sigma^-$, K^+Y^{*-}, ΛK^0. The idea is that different classes of these reactions have different basic quark diagrams (see Fig. 3), from no-quark exchange to one- and two-quark exchange. One gets QCD diagrams from these by adding squiggly lines. Although there are a large number of such diagrams (thousands), G. Farrar has developed computer code to do the work and there will be QCD predictions for them. It is unsettling to be at a computer-arm's length from the physics, but the basic motivation is simple: in hard scattering, do quarks remember where they came from?

If there are significant differences between the cross sections themselves, or between the results and theory, there are a number of future tests which can be concocted: the ρ^-, A_2^-, Δ^-, Y^{*-}, and Λ are all self-analyzing and one can test QCD with polarization (this is a part of the initial experiment); a polarized target, testing dependence on the target spin state; similar tests with other incident particles and targets (neutrons); tests with incident polarized protons to several exclusive final states.

This represents quite an extensive program of exclusive QCD tests which is very different from inclusive experiments at higher energy. To evaluate its relative contribution to understanding strong interactions, we will need to see whether a) reliable QCD predictions are developed for exclusives; b) these predictions are significantly different from, say, statistical models, and c) the measured reactions in the initial experiments have some interesting behavior--i.e., all the ratios are not 1, or some of the particles have significant polarization.

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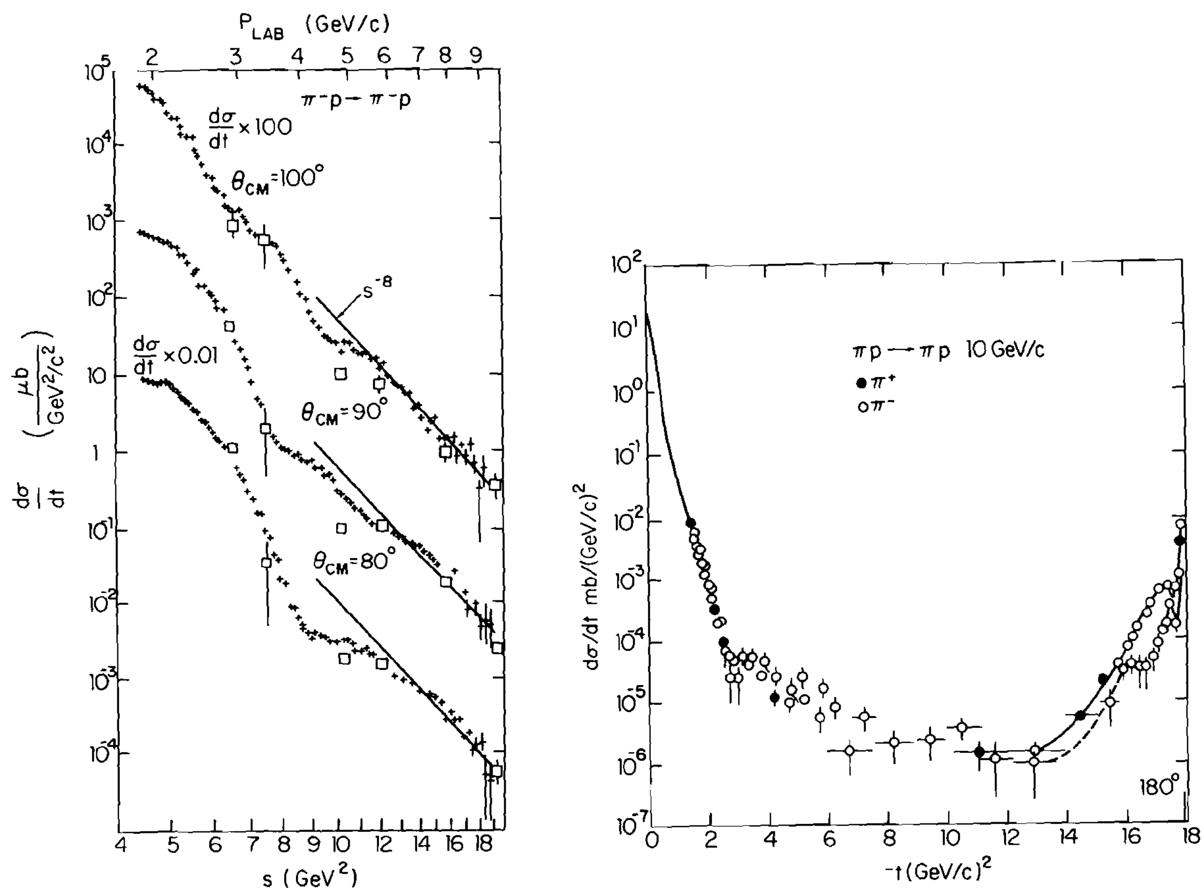

Fig. 1. Data on π^-p elastic scattering at 10 GeV/c from Ref. 5.

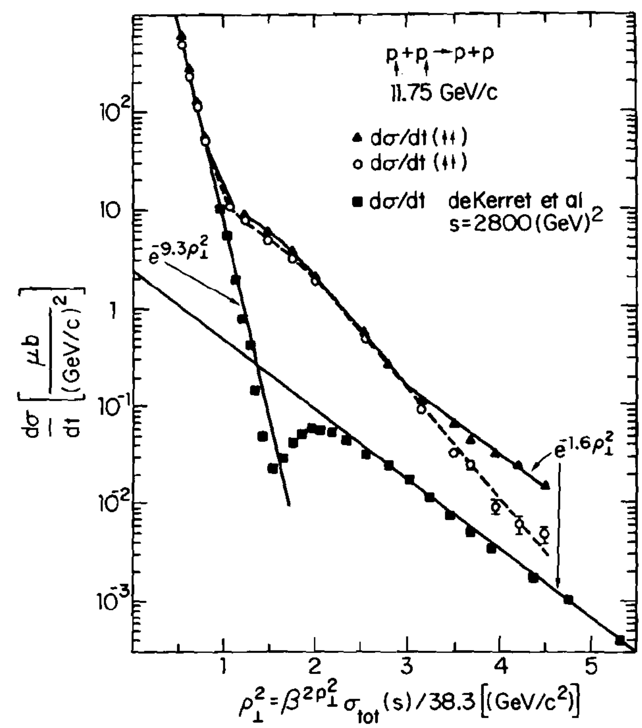

Fig. 2. The proton-proton differential elastic cross section in pure initial spin states is plotted against the scaled $p_\perp^2$ variable (Refs. 2 and 3). Unpolarized ISR data are shown for comparison.

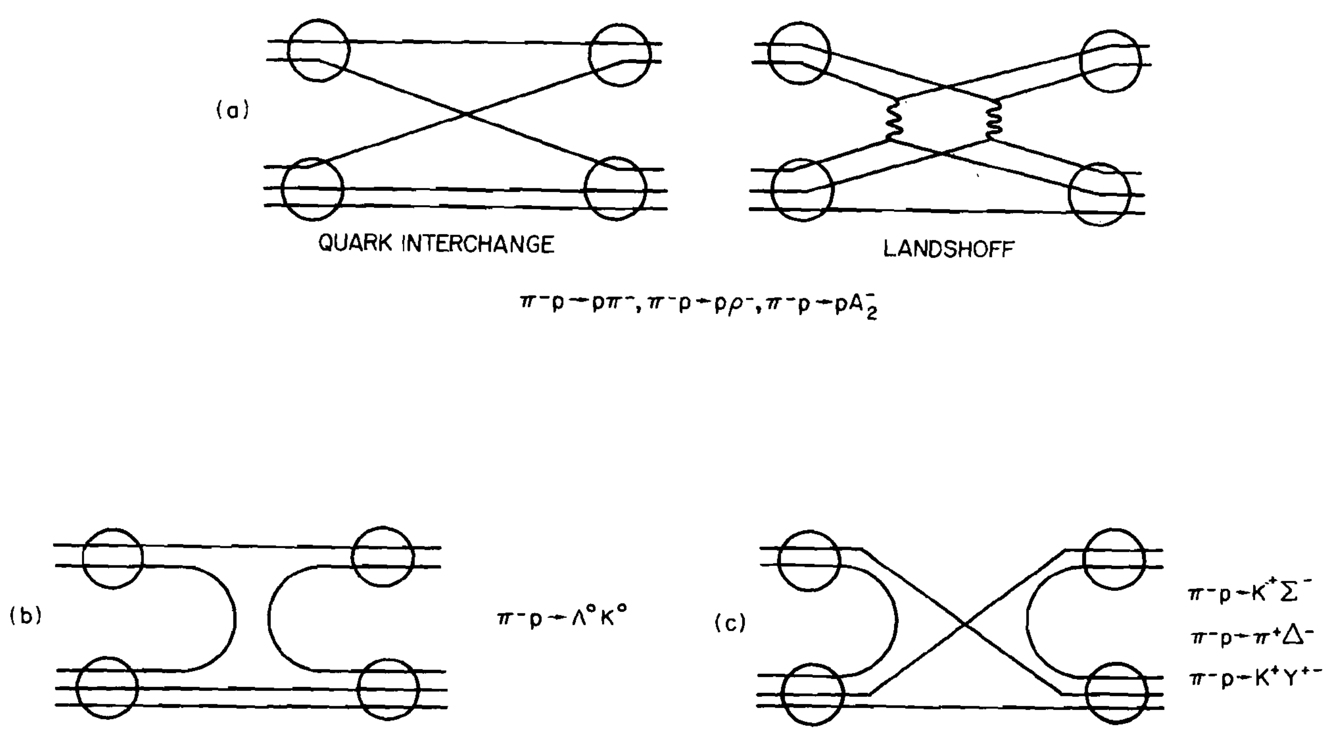

Fig. 3. Quark diagrams for 90° scattering. The reactions listed in (a) can proceed via diagrams (b) and (c). Similarly, $\pi^- p \to \Lambda K$ can also proceed via diagram (c).